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MOLECULAR NITROGEN IN THE UPPER ATMOSPHERE

(O molekulyarnom azote v verkhney atmosfere)

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The question of chemical composition of the upper atmosphere is one of the most important in atmospheric physics. However, it has not been finally solved as yet. If intermixing is being observed in the atmosphere to 100 - 110 km altitudes and the chemical composition is thus known to us, our knowledge of atmosphere composition above 120 - 130 km is fundamentally only limited to various theoretical models considering the gravitational separation of the basic constituents of the atmosphere, and the dissociation of nitrogen and oxygen molecules. At the same time, a precise knowledge of the composition of the atmosphere is prerequisite to further examination of a series of matured questions of upper atmosphere physics, such as for example the explanation of the formation of various ions, of radiation absorption with altitude, the explanation of aurora and night-sky glow, the determination of temperature by density gradient etc...

Only a few years ago it was still estimated beyond doubt, that a gravitational separation of basic constituents takes place in the atmosphere beginning with the 100-120 km altitude range, in correspondence with the barometric formula, and that atomic oxygen is the predominant atmospheric constituent beginning with 150-160 km altitudes. The atmosphere models of Bates, Mitra, Kallmann and others [1, 2, 3] were precisely constructed on the basis of those representations. According to Nicolet [4], the gravitational separation begins only at 160 km, but even according to that model atomic oxygen prevails over molecular nitrogen beginning with the 200 km altitude.

However, a series of new data on upper atmosphere lately obtained with the aid of rocket and satellite investigations, compel us to doubt that the atmosphere is practically composed of atomic oxygen above 150 - 170 km, as this follows from the models referred-to above. Examined are below the basic considerations pointing to the fact, that at greater heights, molecular nitrogen constitutes a substantial dose of the total density.

1. The notion of the presence of gravitational separation between molecular nitrogen and oxygen beginning with the 100 - 120 km altitude is fundamentally based upon probe measurement method [5], and with the aid of mass spectrometer [6] of argon and nitrogen gravitational separation. However, measurements of chemical composition by means of Aerobee rockets [7], and also those carried out by A. A. Pokhunkov on Soviet geophysical rockets [8, 9], show that the ratio of nitrogen to oxygen concentration remains practically constant to 200 - 220 km altitudes, and equal to that near the ground. At the same time, argon and nitrogen separation is observed in all those experiments, beginning with 100-110 km altitudes. Therefore, the existence of separation between argon and nitrogen apparently does not suggest as yet, that separation between nitrogen and oxygen must necessarily exist at those heights. To the contrary, the indicated direct measurements confirm that at 200- 220 km altitudes the N_2 to O ratio is the same as at lower altitudes. It is possible that the difference between the beginning of separation process of atomic oxygen and N_2, and that of argon and nitrogen is related to the chemical inertness of argon, and the high chemical activity of atomic oxygen, which creates some sort of "photochemical intermixing" by continuously combining with the molecular nitrogen through various ion-neutral reactions.

2. In spectrograms obtained on 19 April 1960 by Purcell and others [10], the line L_γ is considerably weakened in relation to to the other lines of the Lyman series at 200-220 and 150-200 km.

This is apparently related to the strong absorption of that line by the molecular nitrogen at altitudes above 200 km [11]. Having estimated on the basis of the spectrograms [10], and of the theoretical significance of lines L_β and L_γ intensity ratio the magnitude

$$\frac{(L_\gamma)_{200}}{(L_\gamma)_\infty} = \frac{1}{6},$$

it is not difficult to compute the number of absorbing molecules N_N in the atmosphere column above 200 km from the correlation

$$\frac{(L_\gamma)_{200}}{(L_\gamma)_\infty} = \exp\left[-N_{N_2}\sigma \sec z\right].$$

Hence, at cross section absorption of the line L_γ by molecular nitrogen

$$\sigma \approx 7{,}3 \cdot 10^{-18}\ см^2 \ [12], \quad \frac{(L_\gamma)_{200}}{(L_\gamma)_\infty} \approx \frac{1}{6}, \quad z \approx 50°,$$

it is easy to find

$$N_{N_2} \approx 10^{17}\ см^{-2}.$$

At the same time, taking atmosphere density at 200 km altitude equal to $3.5 \cdot 10^{-13}$ g $\cdot$ cm^{-3} according to Mikhevich and others [13] and Prister [14], and assuming that the atmosphere is entirely composed of molecular nitrogen at the given altitude, we shall obtain

$$[N_2]_{200} = 7{,}0 \cdot 10^9\ см^{-3}.$$

Admitting the value $5 \cdot 10^6$ cm for the height of uniform atmosphere at that altitude [13], we shall obtain the hypothetical quantity N_2 in the atmosphere column above 200 km:

$$N_{N_2} = 7{,}0 \cdot 10^9 \cdot 5 \cdot 10^6\ см^{-2} = 3{,}5 \cdot 10^{16}\ см^{-2}.$$

The comparison of both values of the magnitude N_{N_2}, determined with a precision to the 2-3 multiplier, shows tha molecular nitrogen

apparently is the basic constituent of the atmosphere at 200 to 250 km altitudes. It must be borne in mind though, that the result of the examination brought forth is strongly dependent upon the magnitude σ. If the admitted value of σ, taken according to the Watanabe curve should be incorrect, and if the absorption cross section of the line L_γ by molecular nitrogen should be higher by one order than the admitted one, the estimated quantity of molecular nitrogen would be considerably decreased. However, the possibilty of such an error appears to be quite unlikely for the following reason: The comparison of spectrograms obtained at 200 - 250 and 150 - 200 km altitudes, indicates that between these altitudes, the intensity of the line L_γ also drops by about six times. At the same time, and inasmuch as at those altitudes there surely is a substantial amount of nitrogen, the line L_γ should be absorbed much more intensely in case of a great absorption cross section.

3. Data on the ion composition of the atmosphere obtained by V. G. Istomin [15-17], allowed the examination of a series of processes of ion formation and vanishing in the upper atmosphere [18 - 20], in which neutral constituents, and particularly nitrogen molecules, also participate. The reactions

$$\begin{aligned} &N_2 + O^+ \rightarrow NO^+ + N \\ \text{and} \qquad &NO^+ + e^- \rightarrow N + O \end{aligned} \qquad (1)$$

were proposed by various authors as an explanation of the NO^+ ion presence in the upper atmosphere. It has been shown in reference [18] that the course of relation

$$\frac{[NO^+]}{[O^+]} = \frac{\gamma}{\alpha} \cdot \frac{[N_2]}{n_e}$$

in the 100 -400 km range, computed from the examination of reactions (1) (in the assumption of dose's N_2 invariability in the total density, i.e. at $[N_2] = \rho k$), coincides very well with the course of $\frac{[NO^+]}{[O^+]}$ obtained experimentally.

Quite analogous results were obtained in reference [20] in the course of the study of ion N_2^+ formation and vanishing. Therefore, the experimental data about the ion composition also point indirectly to the constancy of atmosphere composition to significant heights. The fact that beginning with the 220 km altitude O^+ ions predominate in the ionosphere, cannot serve as a corroboration of the thesis about atomic oxygen predomination at these altitudes, for, on account of the complexity and diversity of modes of formation (and also of vanishing) of atomic and molecular ions, the ionic composition does not reflect directly the neutral composition of the atmosphere.

4. On the basis of the study in a recent work by Nicolet [21], of dissociation and diffusion processes, it was shown, that the equality condition of concentrations of atomic and molecular components

$$\rho(N_2, O_2) = \rho(O)$$

is fulfilled at the altitude, where the total density $\rho = 4.5 \cdot 10^{-15}$ $g \cdot cm^{-3}$. According to reference [13], such density corresponds to 430 km altitude. Inasmuch as molecular oxygen is practically absent at such great altitudes, this condition implies that molecular nitrogen must constitute half of the total density even at 430 km altitude.

The question of a strong molecular nitrogen dissociation in the upper atmosphere is at present being answered negatively. Despite a fairly high rate of nitrogen atom formation by photochemical reactions [22], the dose of nitrogen in the total neutral density to 400 km altitudes is very small. The fact that atomic nitrogen ions are present in the atmosphere and that the glow of lines NI is observed, may be explained without having to resort to substantial N concentrations, as has been shown in references [23] and [24].

Thus, there is at present a good basis to assume, that nitrogen in the form of molecules is present in significant quantities in the upper atmosphere, to altitudes of the order of 400 km.

**** E N D ****

REFERENCES

1. D. R. BATES. Proc. Roy. Soc., A 236, 206, 1956.
2. S. K. MITRA. Verkhnyaya atmosfera (Upper Atmosphere), IL, 1955.
3. H. K. KALLMANN. J. Geophys. Res., 64, 615, 1959.
4. M. NICOLET. From "The Earth as a Planet", Chic.Un.Pr., 654, 1954.
5. B. A. MIRTOV. UFN, 63, vyp.1, 194, 1957
6. J. W. TOWNSEND, E. B. MEADOWS, C. Y. JOHNSON. IGY Rocket Report Series, No.1, 131, 1958.
7. J. W. TOWNSEND. From "Phys and Med. Atm.and Space, John Wiley & Sons, Inc., p.112, New York-London, 1960.
8. A. A. POKHUNKOV. Izv. A.N. SSSR, ser.geofiz., No.11, 1649, 1960.
9. A. A. POKHUNKOV. Sb "ISZ" (AES), v.7, p.89, 1961.
10. J. D. PURCELL, S. R. DETWILER, I. R. TOWSEY. Les spectres des Astres dans l'ultraviolet lointain, p. 253, Liege 1960.
11. H. FRIEDMANN. Trans. Intern. Astr. Un. 10, 706, Cambridge U.P.1960.
12. K. WATANABE. Adv. Geophys., 5, 133, 1958.
13. V. V. MIKHNEVICH, B. S. DANILIN, A. I. REPNEV, V. A. SOKOLOV. Sb. "ISZ" (AES), v.3, p. 84, 1959.
14. W. PRISTER, H. A. MARTIN. Bonn Univ. Obs.Rep., No. 29, 1960
15. V. G. ISTOMIN. Sb."ISZ" (AES), vyp. 4, p. 171, 1960.
16. V. G. ISTOMIN. Dokl. A.N.SSSR, 129, 81, 1959.
17. V. G. ISTOMIN. Sb."ISZ" (AES), v.7, p.64, 1961.
18. A. D. DANILOV. Sb."ISZ" (AES), v.5, p. 60, 1960.
19. A. D. DANILOV. Dokl. A.N.SSSR., 137, 1098, 1961
20. A. D. DANILOV. Sb."ISZ" (AES), v.8, p.72, 1961.
21. M. NICOLET. Planet. Space Sci., 5, 77, 1961.
22. A. D. DANILOV. Geomagnetizm i Aeronomiya, 1, 174, 1961
23. A. D. DANILOV. Ibid., 1, 314, 1961.
24. A. D. DANILOV. Ibid. 1, 45, 1961.

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